HANDBOOK FOR ENERGY EFFICIENT RESIDENTIAL SUBDIVISION PLANNING

3

Design Implications

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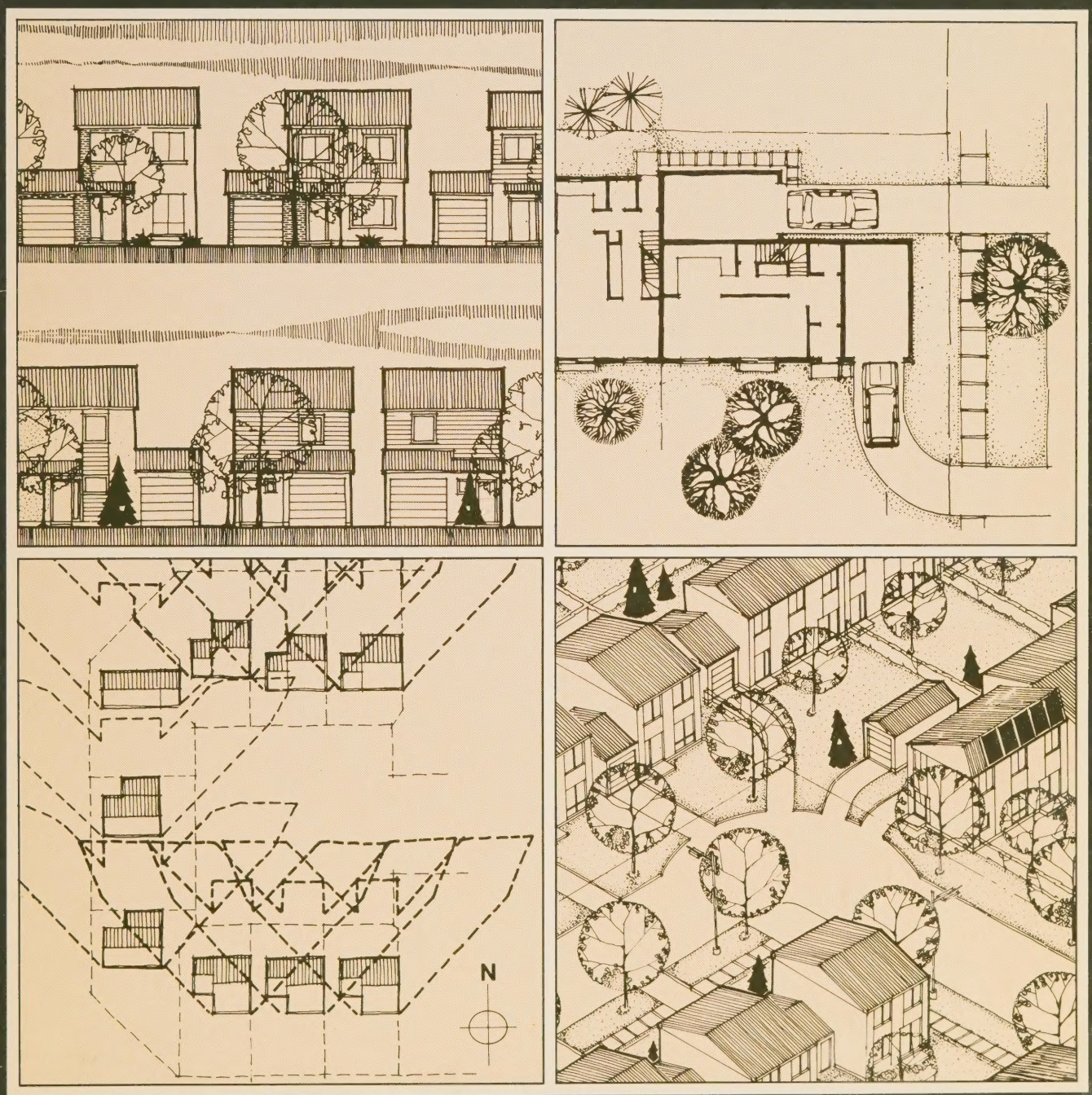

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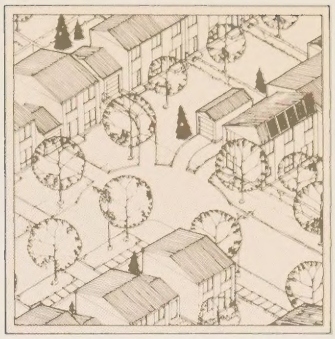


Ministry of Municipal Affairs
and Housing

Research and Special Projects Branch

Handbook for Energy Efficient
Residential
Subdivision Planning

Part 3:
Design Implications

Ministry of Municipal Affairs and Housing

Research and Special Projects Branch

August 1984

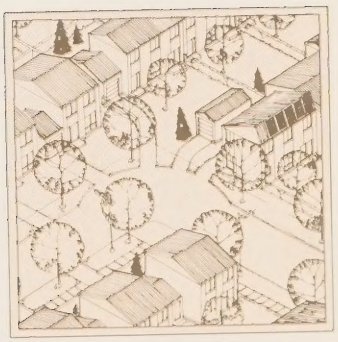
Available from:
Ontario Government Bookstore
880 Bay Street
Toronto, Ontario
M7A 1N8

Price $5.00
payable to the
Treasurer of Ontario

ISBN 0-7743-9548-6

PART 3

Design Implications



In January 1981, the Ministry of Housing issued a report on *Residential Site Design and Energy Conservation*. This basic study examined the possibilities of saving energy from conventional sources used for space heating. Houses were located within a subdivision with the main window areas facing south to utilize the radiation from the sun. This *Handbook for Energy Efficient Residential Subdivision Planning* is a consequence of the basic study.

Contents

Introduction

Purpose

The Handbook for Energy Efficient Residential Subdivision Planning provides a comprehensive design guide for municipal planners and land developers.

This part of the Handbook deals with the design implications of developing a low density residential subdivision that takes account of local sun and wind conditions. These design changes affect a subdivision layout (in terms of street orientation, lot orientation and sizes), building (shape, type, orientation, window arrangement and roof), landscaping (size, type and location of trees), and yield (the number of lots and leaseable frontage).

Part 1 (Overview) of this Handbook series deals in a general way with the basic site design considerations (the orientation of a street, lot, dwelling unit, etc.). This part (Design Implications) considers more fully the impact of these design issues in the context of the residential street appearance and detailing of the subdivision layout.

Background

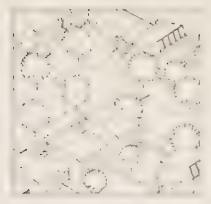
In response to higher fuel costs, energy conservation in housing is usually promoted through improved standards of construction, such as, more insulation, better use of vapour barriers and the installation of more efficient furnaces. As well, specialized building designs are, from time to time, introduced that use such features as super-insulated double walls, active solar devices and forced air circulation. These improvements carry an economic cost which, under the present fuel pricing structure and relatively high mortgage rates, is hard to justify to the average consumer. The immediate cost tends to be the major consideration rather than energy conservation.

This Handbook series takes a different approach to energy savings. Instead of considering improvements to the building structure, it concerns itself with house orientation and the use of sunlight to reduce energy costs. The vast majority of the measures described are cost free. In the few which result in added costs, such as night blinds, the pay-back period is relatively short. Also, there is the possibility that on a subdivision scale there will be some savings in terms of servicing and gains on lot yield.

However, the design criteria required to achieve energy savings in residential developments at no additional construction costs result in somewhat different streetscapes than those usually found in a low-density residential development.

Members of the housing industry suggest that appearance is the area where some consumer hesitation could be encountered. Home buyers protect their investment by purchasing houses with assured re-sale potential: they tend to be cautious about innovation. This part of the Handbook investigates this subject emphasizing practical aspects and marketability. It looks at all the elements that constitute a low-density residential development — highlighting the differences between the traditional and the energy-conserving design approach.

The new design issues



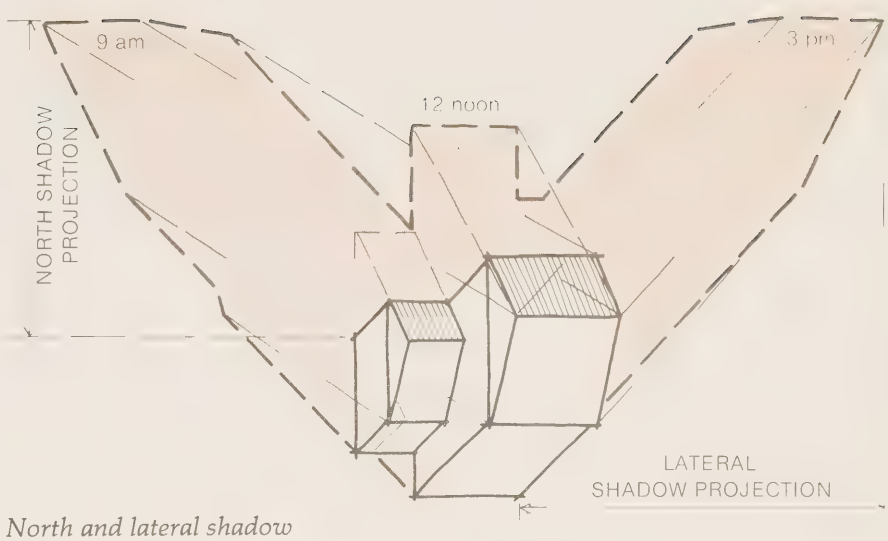
Lot and street orientation

In the passive use of solar energy for space heating purposes the orientation of appropriately designed buildings is of paramount importance. This orientation is only easily achieved if the street pattern facilitates the orientation of lots in the general direction of north-south along their depth.

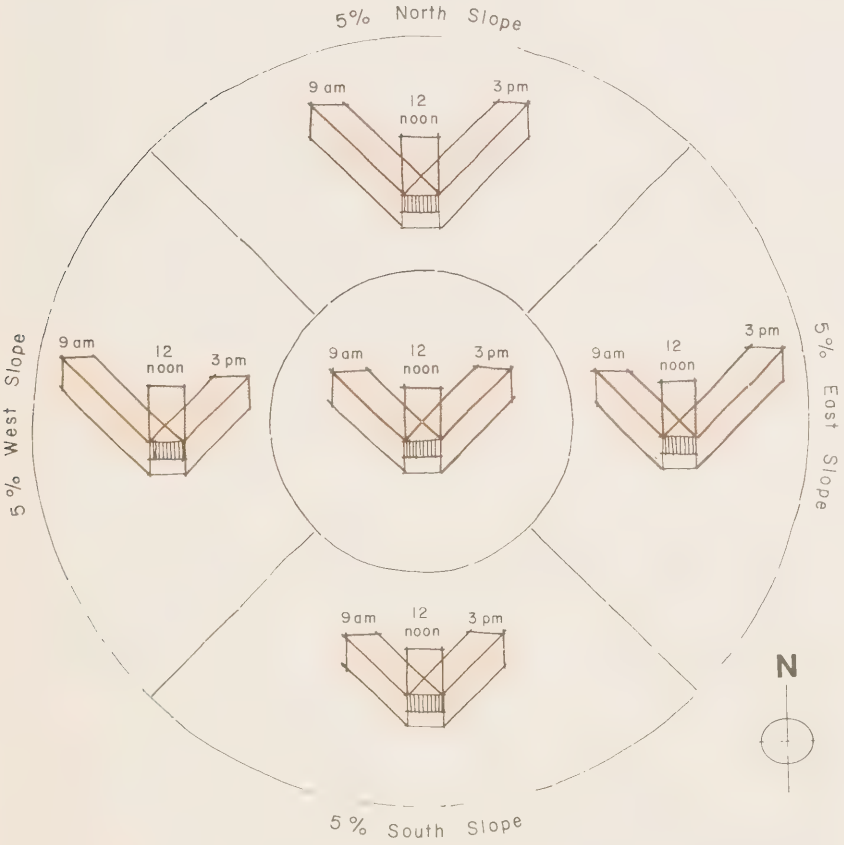
Lot configurations are related to:

- The north shadow projection of buildings.

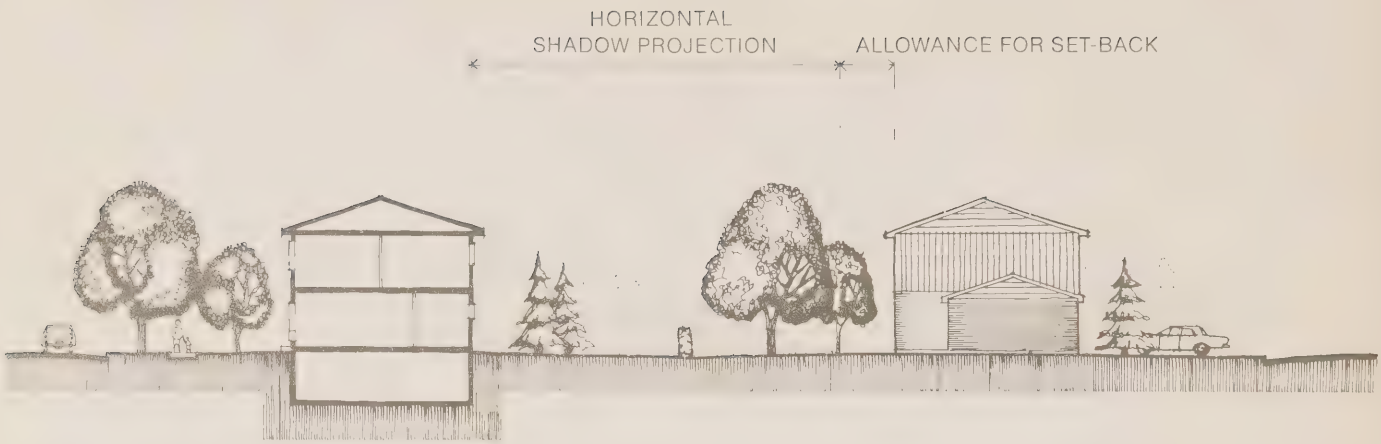
  This distance determines the appropriate lot depth and is affected by the building height, latitude and slope directions.



North and lateral shadow projections.



Topography influences the height of shadows cast by buildings. Northern slopes generate the longest shadows.



Horizontal Shadow Projection — Section View.

Building design also plays a role in the determination of lot size because it establishes the height of the south-facing window sills. At 44° north latitude (for example, at Trenton or Toronto), the north-south distance separating buildings can be reduced by approximately 3.5 feet/1 metre for every foot that windows are above horizontal ground level.

- The lateral shadow projection of buildings.

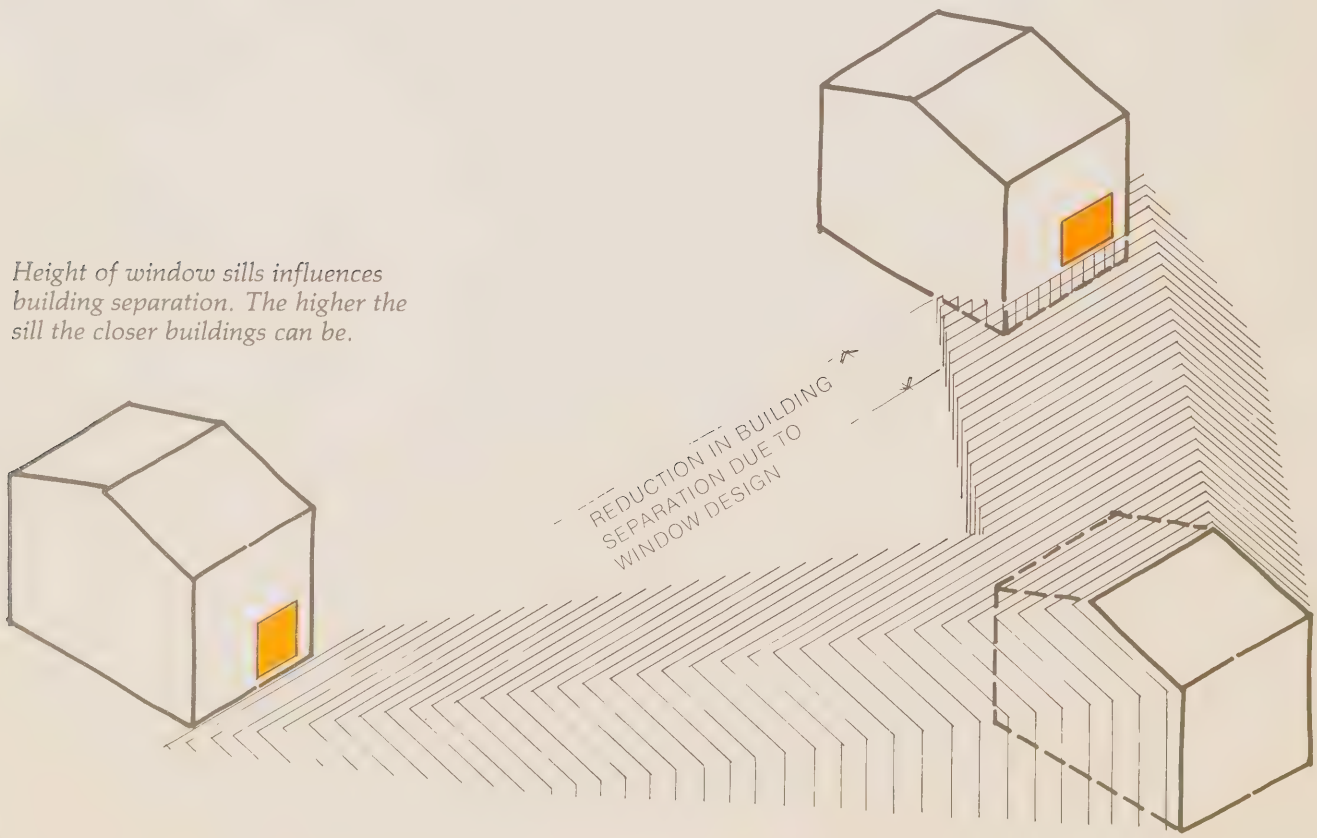
  This distance determines the appropriate lot width and building set-backs. In general, the set-back can be as great as the distance that separates buildings.

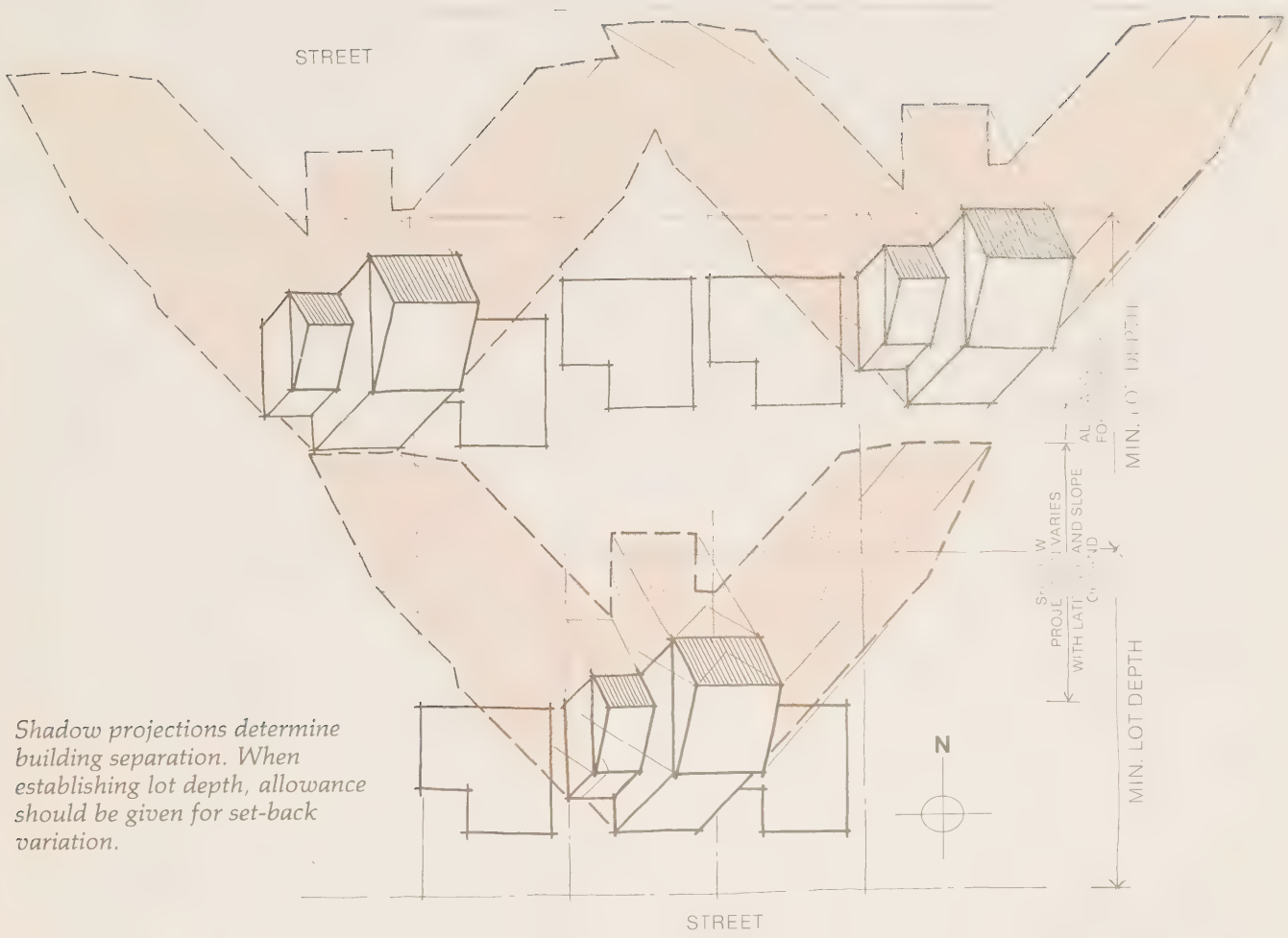
  Lateral shadow projections are a function of the bearing angle of the sun for a particular design period.

- The type and orientation of the street on which the lot is located.

  The lotting arrangements need to be adapted to whether a street has:
  — an east-west orientation
  — an orientation diagonal to east-west
  — a north-south orientation
  — a cul-de-sac configuration.

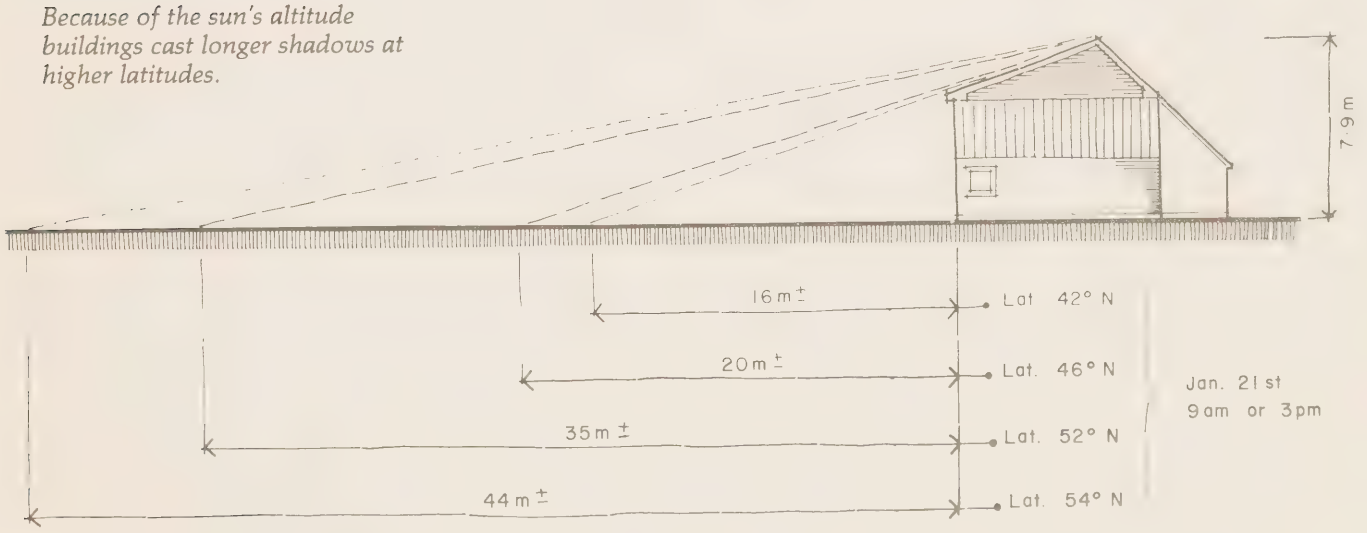
Height of window sills influences building separation. The higher the sill the closer buildings can be.

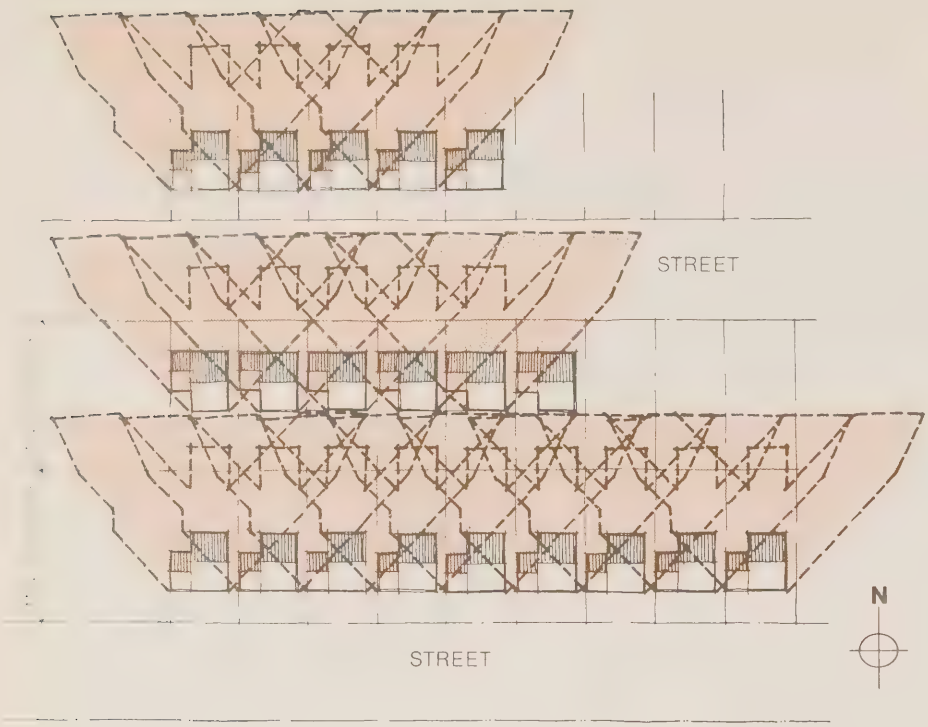




Shadow projections determine building separation. When establishing lot depth, allowance should be given for set-back variation.

Because of the sun's altitude buildings cast longer shadows at higher latitudes.



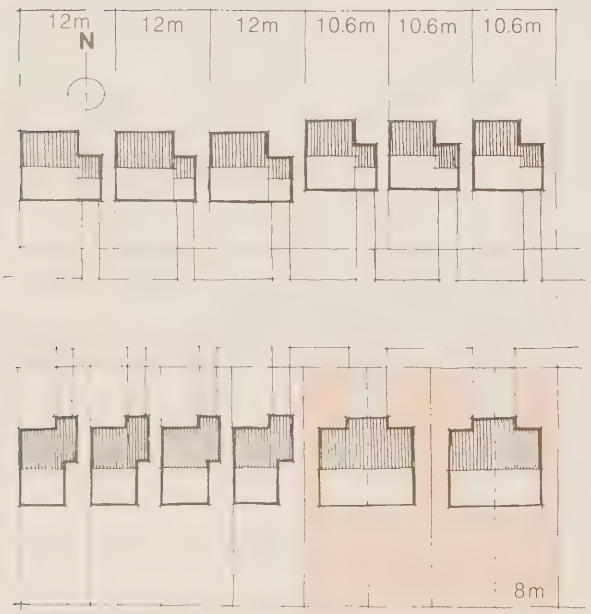


All day shadow pattern of buildings sited on east-west streets.

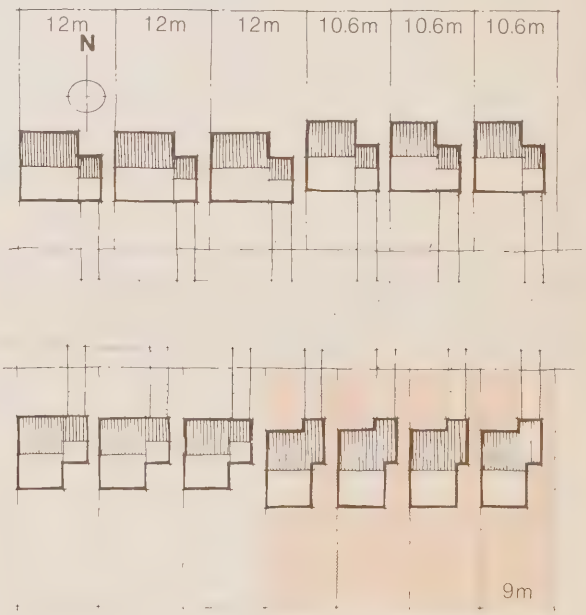
There are two popularly-held concepts about a street pattern in a residential subdivision designed to make use of the sun and minimize the effect of the wind during the heating season: the absolute necessity for east-west streets and the limitation on the use of cul-de-sacs. Both these notions are largely incorrect.

Streets that tend towards an east-west emphasis offer the best opportunities for solar access on houses sited on conventional lots. Also, the shadows cast by structures fronting on to east-west streets are such that the lot depth and width requirements are smaller than on any street orientation. There is, however, no need to stick to the strict interpretation of an east-west direction and end up with long sterile-looking streets. Dwellings can be oriented 15 degrees east or west of due south without significantly reducing the potential for solar gain.

Not all unit types are appropriate to both sides of east-west streets. Because of the traditional location of the garage and entry, semi-detached and town housing can only be used to real advantage on the south side of the street. On the other hand,



Because semi-detached units usually have the garage in front they should be placed on the south side of the street to expose the rear wall to the sun.

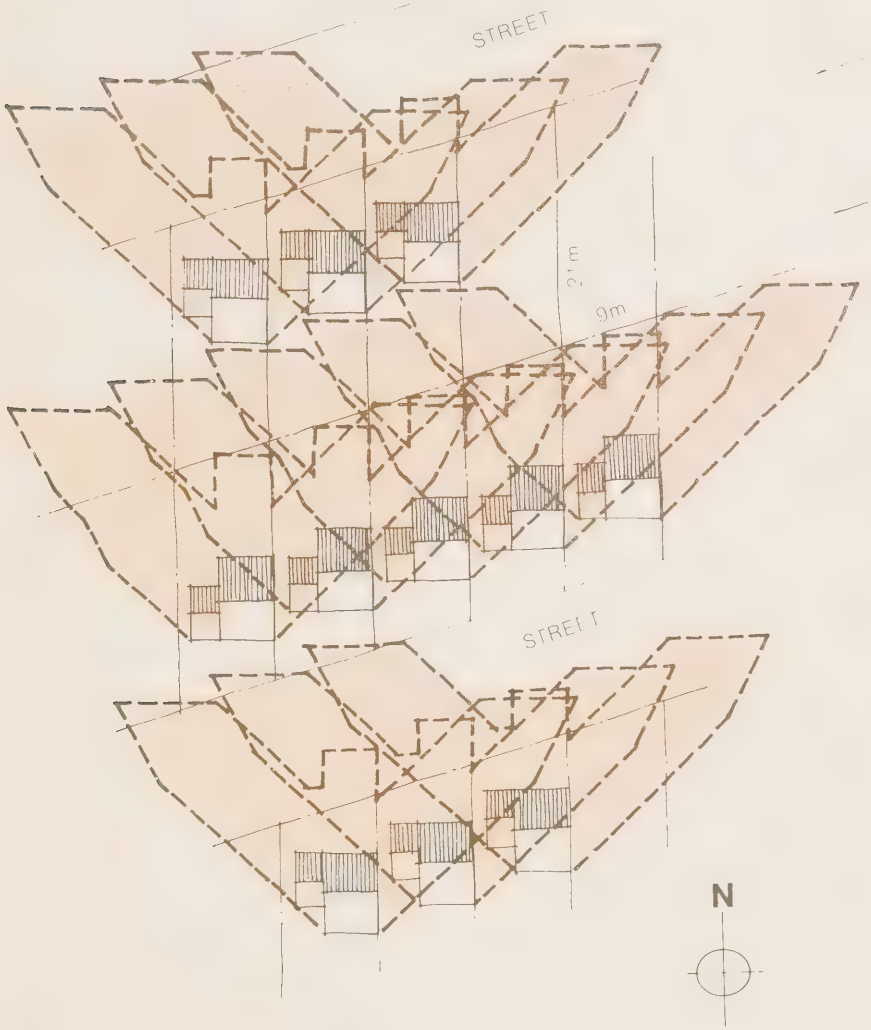


If lots with frontages smaller than 35 feet are to be located on E-W streets they should be sited on the south side of the street to avoid obstructing with the garage wall most exposed to the sun.

detached units can easily be adapted to either side of the street. However, in the case of small detached units on narrow lots (30 feet/9 metres), the south side of the street is the preferred location so that the wall exposed to the sun not be unduly obstructed by the garage or the lot depth increased. Lots 35 feet/10.5 metres and up are wide enough to accommodate the house and garage without the creation of severe shading conditions. There is no need to have a lot-width variation of more than 5 feet between lots on the north and south sides of an east-west street.

Streets that run at an angle to the east-west axis offer both problems and benefits.

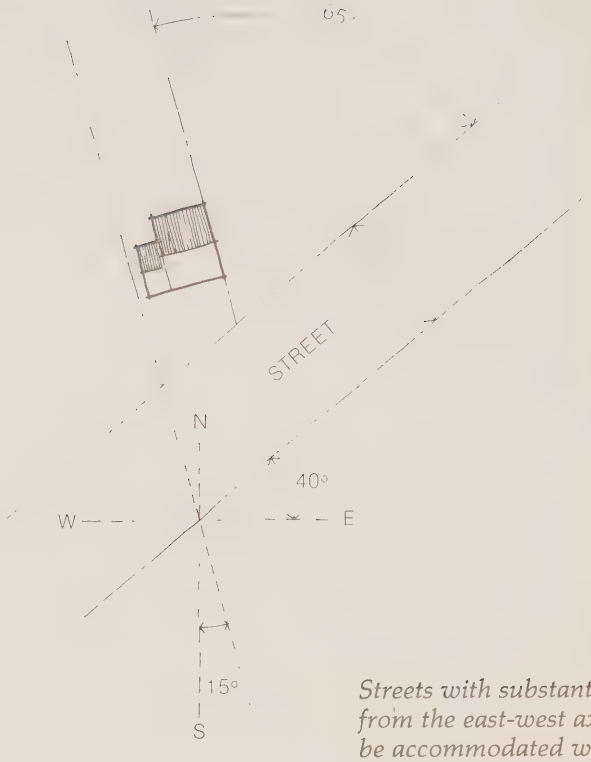
When the skew of the street is of small magnitude (15° max) the lots can be defined in a traditional fashion without appreciable loss in solar exposure to the buildings.



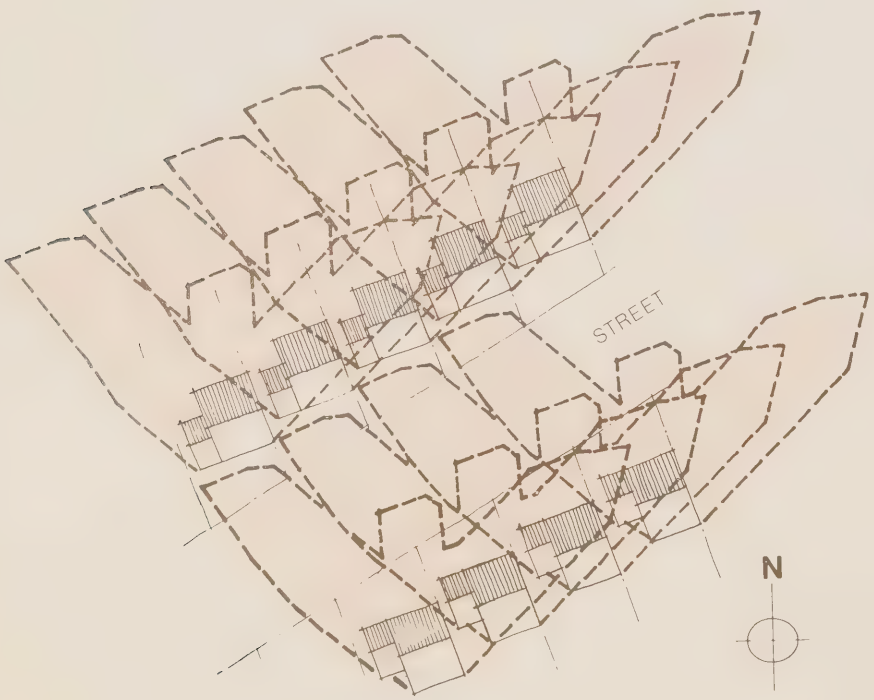
Optimum orientation can be obtained by skewing the lots enough to compensate for the street alignment.

The difficulties arise from the fact that if the deviation from the east-west axis is greater than 15 degrees the loss in the available heat gain from direct radiation starts to become substantial. For example, when dwellings are sited 30 degrees off due south, there is a loss of about 15 percent of the potential direct solar radiation. Moreover, as the angle of the street increases so does the lateral shadow cast by the buildings. Lots of ever-increasing widths are required to offset this effect.

The problems created by these streets can be eliminated by skewing the lots so that the side lines are kept within 15 degrees of south. This technique, provided that the streets are no more than about 40 degrees off the east-west axis, requires skews of modest magnitudes. The advantages of this approach are the greater privacy obtained in the back yard, and, when confined to short lengths of road, the added variety in the street scene.



Streets with substantial deviations from the east-west axis can be accommodated without compromising the building's solar exposure.



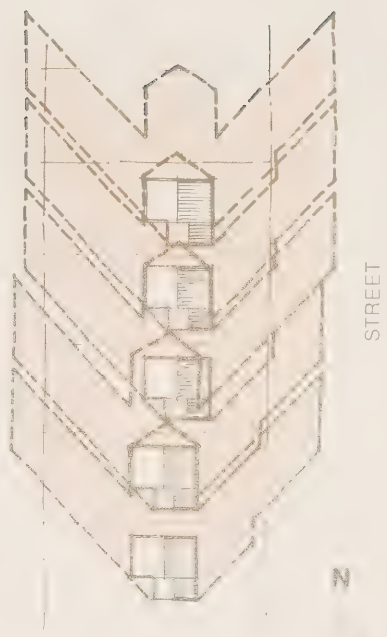
If the street deviates from the E-W alignment by more than 15° greater lot skews are necessary and ideal building orientation may not be possible.

Streets that run north-south pose a special problem when lotted in a traditional fashion, since the alignment of these streets poses the most limitations of the full use of the available solar radiation. Conventional arrangements expose to the south a side wall of the building which, in the vast majority of the cases, has the least glazing that it is also almost completely shaded by the adjacent building. In these situations, the living room has access to less than 50 percent of the available direct radiation.

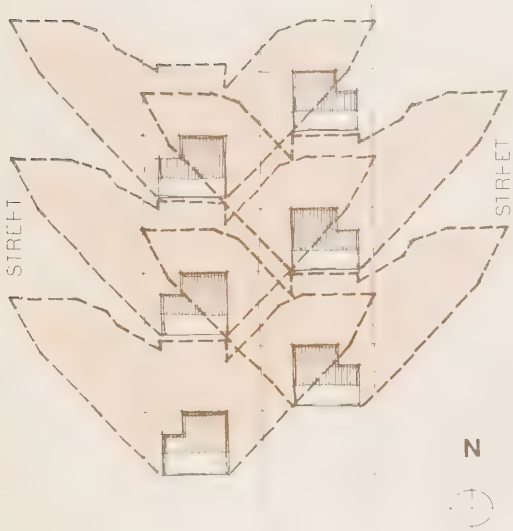
To overcome these difficulties a range of solutions are possible:

- Elimination of frontages by flanking houses on these streets.

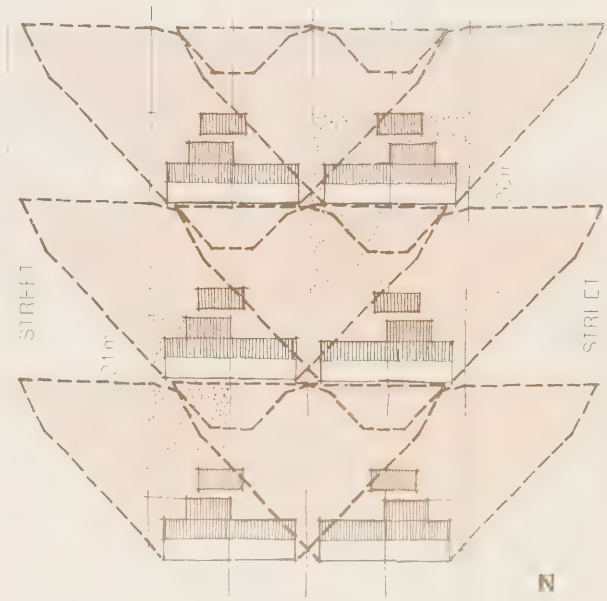
  Although this may result in a number of cross streets, the solution is more acceptable in terms of traffic flow than individual driveways from lots adjacent to the street.



Traditional lot arrangements on north-south streets do not allow for proper solar exposure by the buildings. The facade of the house with the livingroom window is in shade for the greater part of the day.



A checker board lot pattern and appropriately designed buildings eliminate the problems created by north-south streets. Here houses can have their living areas exposed to the sun all day.



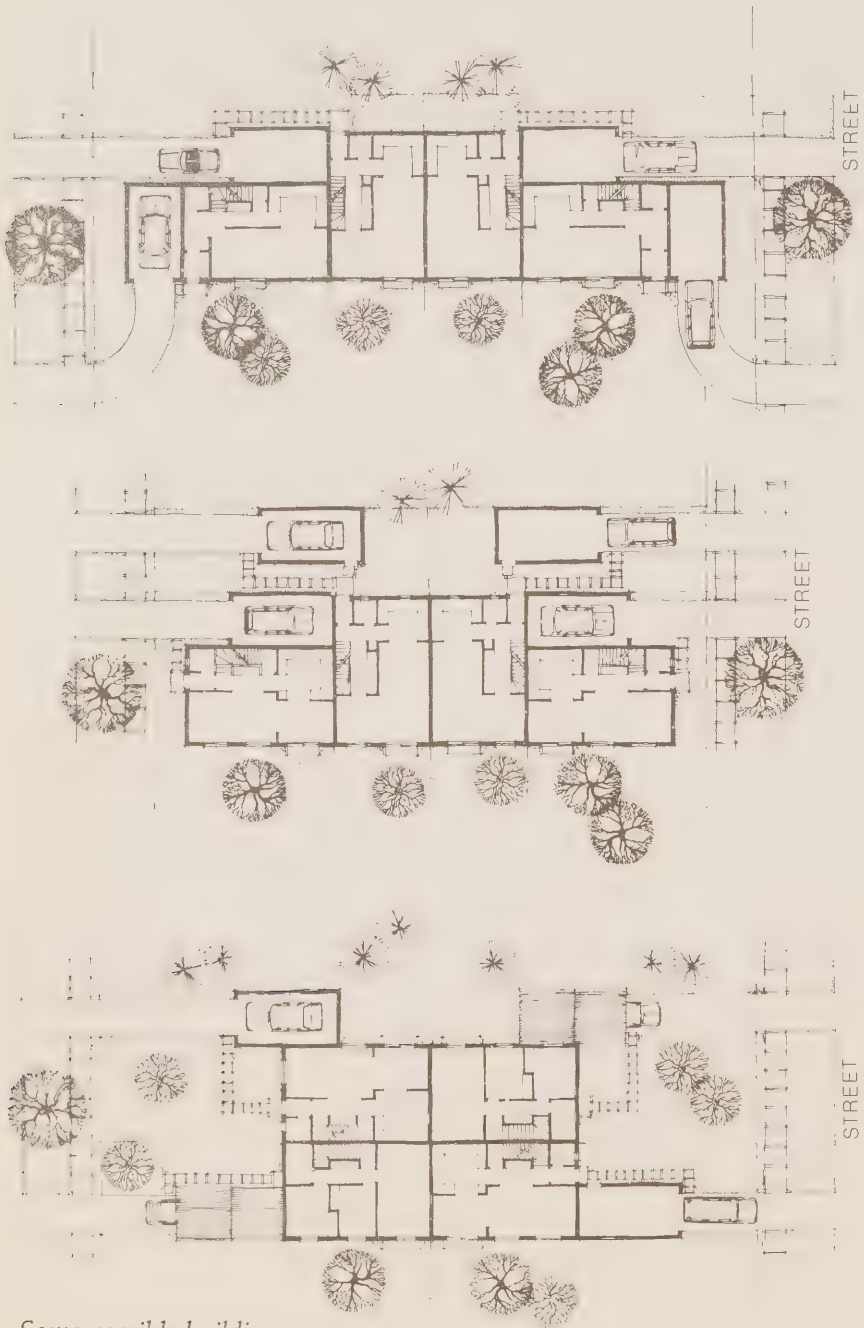
Key shaped lots and attached buildings provide good solution for areas fronting on north-south streets. Shading indicates two types of lots in this layout.

- Exclusion of detached houses from north-south streets.

  Detached houses are the least energy efficient of the three types dealt with in this report. Substituting them by semis or town houses would allow a loss of solar heat to be compensated by a gain in energy efficiency because of the shared walls.

- Use of unconventional lotting arrangements.

  Specially designed lots and appropriate house plans can achieve a desirable orientation for buildings on north-south streets without loss of yield. The privacy obtained on the living room side could be an important feature in the marketing of these units.



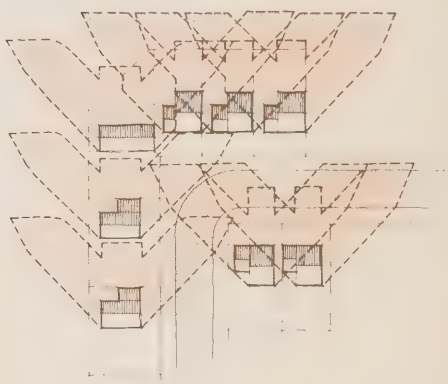
Some possible building arrangements for north-south streets.

Streets in the form of cul-de-sacs have lots that face in virtually all directions. In order to control the orientation of the houses the lots need to have a shape suitable for the siting of south facing buildings. This is achieved by applying the principles used on east-west and north-south streets to the cul-de-sac bulb. The "neck" of the cul-de-sac should be treated in the same manner as the three previously discussed street types.

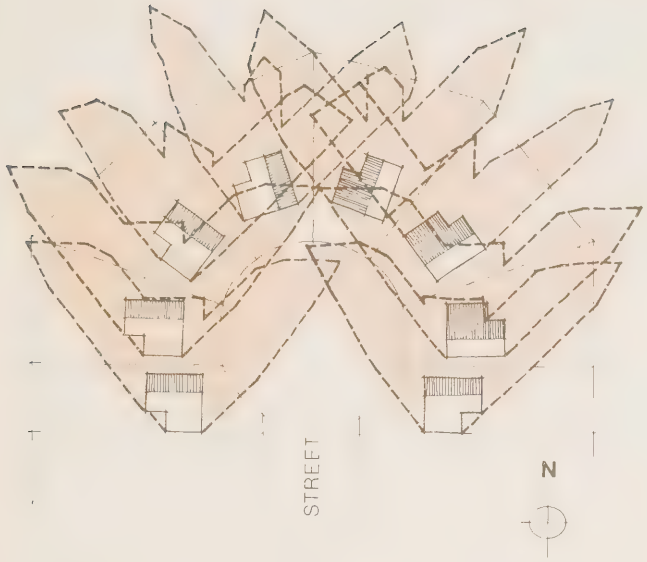
The solution for cul-de-sacs are applicable to all situations where sharp curves occur in the street line.

Conclusion
(lot and street orientation)

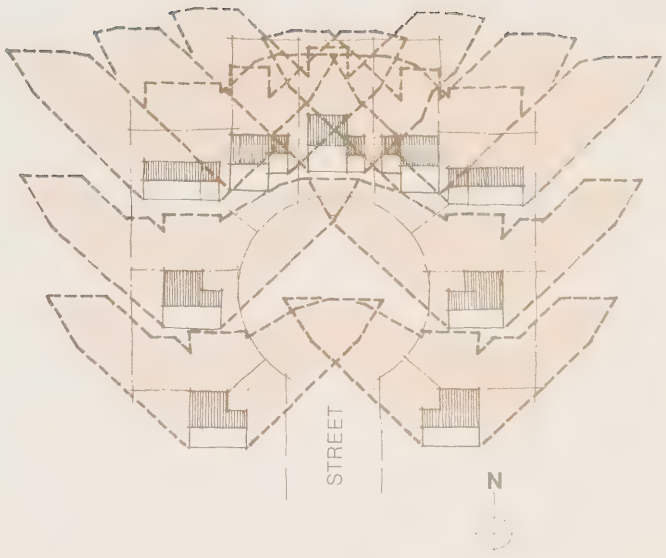
What this all means is the use of streets with east-west orientation need only be a general design principle. The avoidance of excessive engineering costs, the safeguarding of natural features, the curving of a street for aesthetic, functional or marketing reasons — these are all valid trade-offs that can normally be accommodated without losing too much solar radiation potential.



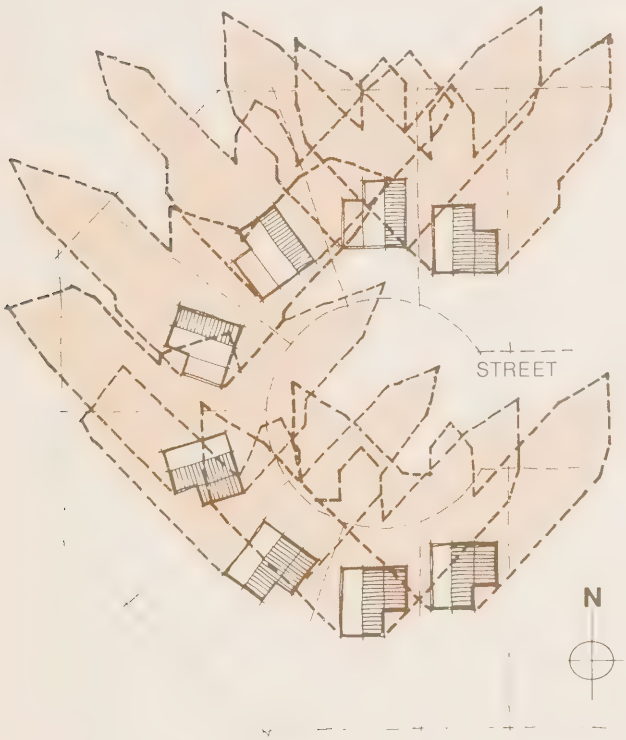
Appropriate building types and lot configurations will eliminate overshadowing on curves.

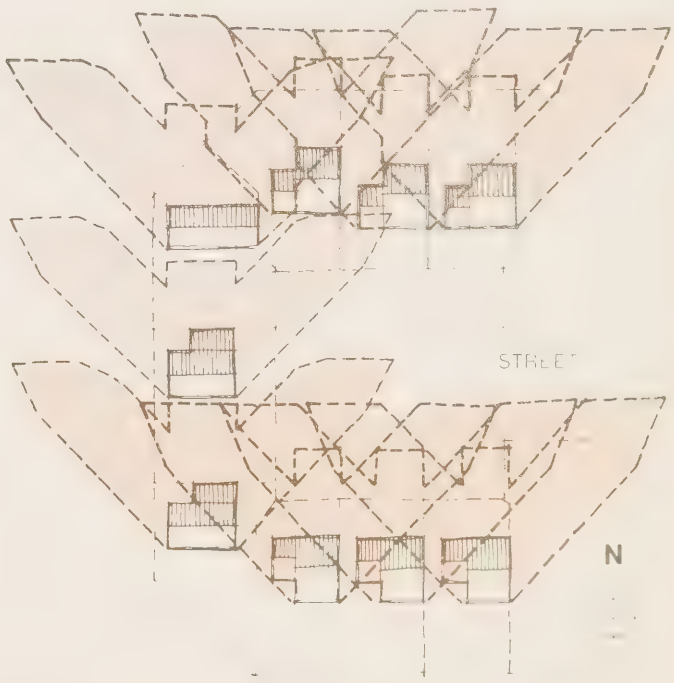


Traditional lotting on a north-south cul-de-sacs causes most buildings to be in shade most of the day.



With more flexible lot shapes and the right choice in building design overshadowing can be eliminated completely.





East-west cul-de-sac — traditional and improved layouts. Note the absence of overshadowing and the increased yield in the improved layout.

Building Design, Type and Siting

Without proper building design, the measures taken at a subdivision plan level could be nullified. It is pointless, for instance, to site on an east-west street buildings which have their walls with the largest area of glazing facing north.

Unlike past development practice, energy saving developments require house designs which are adequate, not only for a particular street orientation, but also for each side of that street. This however is not as difficult as it may sound, since appropriate house designs are readily available. Their use, however, is normally indiscriminate.

The general rules for the successful use of solar radiation by buildings are:

- Use attached housing whenever possible.

  These are the most energy-efficient units in a low-density subdivision.

- Use compact two-storey houses when detached housing is required.

  These require less energy than single-storey units of an equivalent area.

- Provide a south aspect for rooms with the largest windows.

  These rooms should be the ones where most activity occurs such as living rooms, dens and dining rooms.

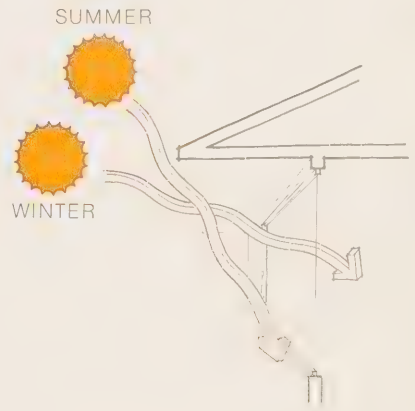
  The internal layout of the houses presently being built no longer must have the living room facing the street. Energy conservation in no way restricts the opportunities for variation on room positioning but requires careful siting of whatever designs the builder intends to market.

- Minimize the window area on a north wall.

  This lessens the transmission and infiltration heat losses. It is possible that this feature could create a problem to some house purchasers. However, the normal subdivision house will almost certainly have need for some north-wall windows. On the other hand, the factors of added privacy and smaller heating costs should have some weight in the final analysis.

Attached buildings save energy.

Apart from some reduction in the amount of glazing the opposite sides of an east-west street may not be too different. On the north side of an east-west street tall evergreens should be avoided.



Overhangs are beneficial in summer and when properly designed will not block the winter sun.

- Locate the garage to protect the north or west wall.

  Even though, in principle, the garage should protect the unit from the prevailing winter wind, it is likely that in a grouping situation, where the houses themselves shelter each other, the function of the garage becomes less critical. Therefore, apart from those homes located in the periphery of the development, the garage location could be left to the designer's discretion.

- Use darker rather than lighter exterior colours.

  The former tend to absorb more of the solar energy and so reduce the heat loss through transmission.

- Control summer cooling by appropriate construction details such as roof overhangs, the use of shading provided by trees, and the channelling of wind for cross-ventilation by the use of vegetation.

- Encourage the use of night shades to reduce the transmission heat loss through the window after the sun has set.

- Consider the use of triple glazing on north-facing windows.

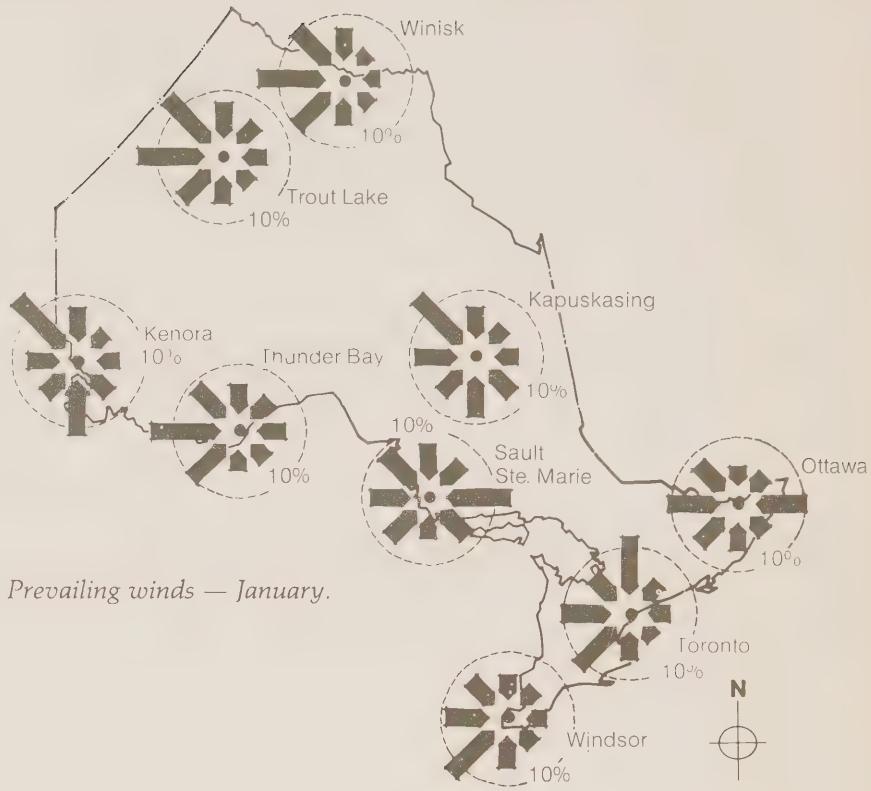
  In most cases, this action may not be too cost-effective. It is more important that window area on north faces is minimized.

- Provide for the incorporation of active solar devices at some time during the life of the structure.

  Roofs, for example, could be designed with appropriate slope on the south side to allow for the possible retrofitting of solar panels. The ideal roof angle is obtained by adding 15 degrees to the latitude at which the house is located.

Once proper lot orientation is achieved in the subdivision plan, the siting of the buildings should not pose any particular difficulties. It must be remembered that traditional developments have no less potential for monotony than energy conserving ones. In terms of appearance, the main difference may relate to the dissimilar amount of glazed area on the streetside facade of houses located on east-west streets. Proper architectural treatment and careful choice of materials should minimize the impact of these differences.

The traditional methods of creating diversity that are available to the builder are equally applicable to energy efficient developments. Set-backs can vary, roof lines can change and different exterior materials can be used.



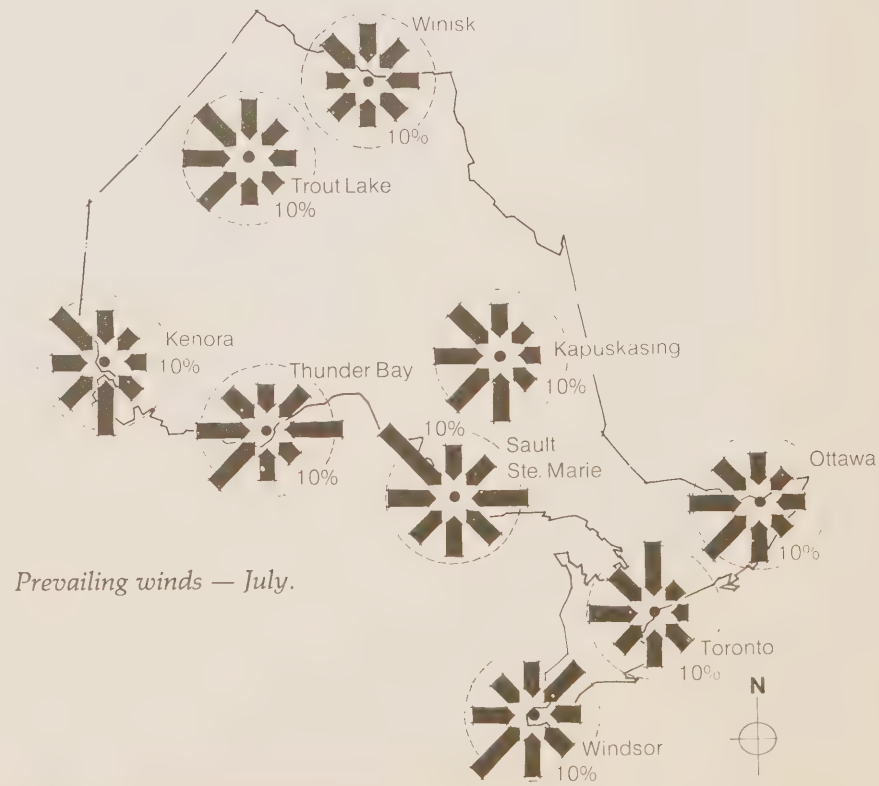
Prevailing winds — January.

Landscaping

Landscape planning for energy efficiency in cold climates must achieve two objectives:

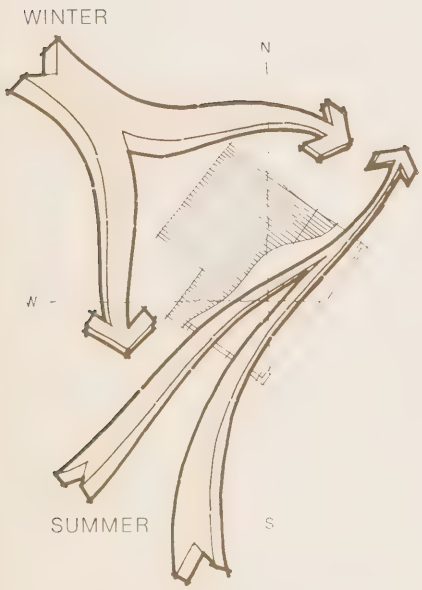
- In the heating season, to shelter buildings from winds, and allow the maximum sunlight penetration in living areas of houses.
- In the non-heating season, to shade buildings from the sun and channel cool breezes to the houses.

Effective wind controls demand a site analysis, including the speed, frequency, and direction of prevailing winds, slopes and vegetation types and positions of neighbouring buildings or structures which may influence the pattern of airflow. If the prevailing winter wind differs from the summer wind, there is no problem in planning landscape to manage both objectives. If summer and winter winds come from the same general direction, however, there could be a problem in satisfying both objectives.

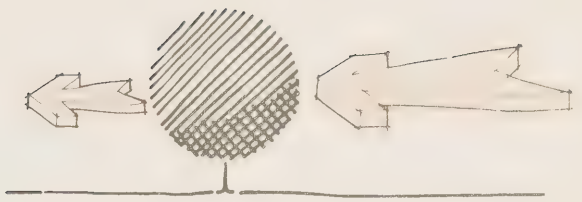


Prevailing winds — July.

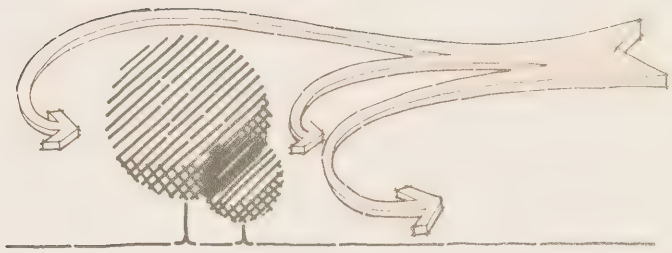
The type of species and location of plants are important aspects of energy-efficient landscape planning. Dense and tall evergreen trees that branch to the ground and shrubs in rows provide the most effective windbreak that can be planted close to and upwind of a building to divert cold winds upwards. In general, rows of windbreaks are far more effective than those planted in small clusters. Trees planted singly are largely ineffective for wind control. Consequently, planting for energy conservation on a lot basis is largely ineffectual. The selection of plants for the southern exposure of a building is important for both a passive solar heating system, such as south glazing areas, and active rooftop solar collectors. A medium height deciduous tree planted close to a house on the south side is desirable for summer shading. However, it must be properly maintained (mainly, by eliminating lower branches) to avoid blocking the desirable winter sun.



When the winter winds and summer breezes do not come from the same direction it is possible to site and design buildings to block the former and take advantage of the latter.

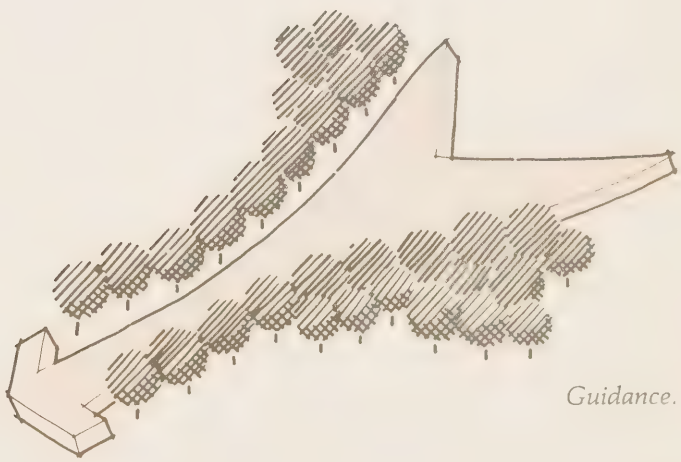


Filtration.

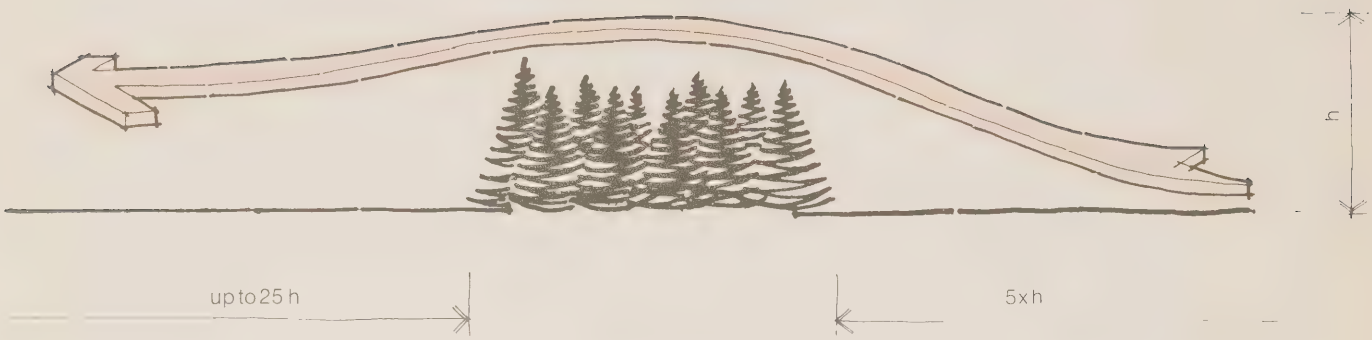


Blockage.

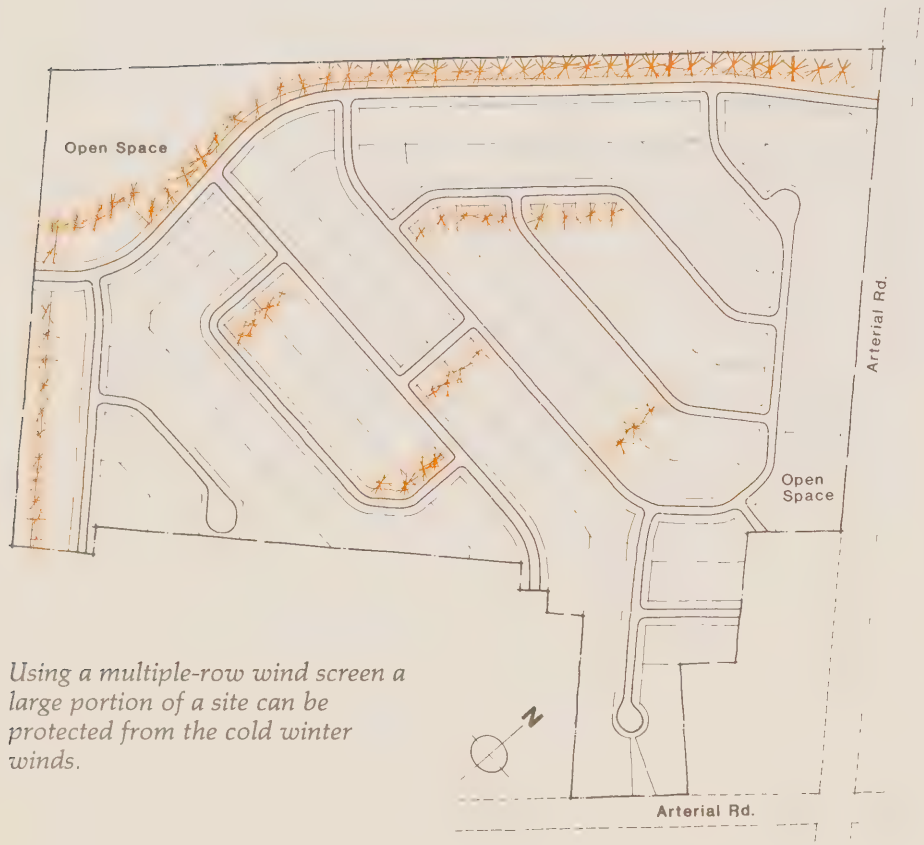
Deflection.



Guidance.



The protection of a wide evergreen barrier can be substantial.



Using a multiple-row wind screen a large portion of a site can be protected from the cold winter winds.

An entire site can be screened from the cold winter winds by dense evergreen planting on the north and west boundaries. On large sites additional rows of trees at right angles to the wind will be necessary. This method is effective but has disadvantages. While it is effective in reducing wind speed, it does nothing to create shading of the individual lot in the summer. Also it requires a substantial amount of land where the trees are planted, and it is an expensive way of using up the landscaping budget without contributing the optimum to the aesthetics of the development.

There is likely to be very little change in street appearance because of planting to conserve energy. There will be more evergreens used on the west side of selected lots, blocks or boundaries, but this change is not expected to create visual problems.

Relationship to development factors

Design changes in subdivision are illustrated by using actual draft plans for three residential developments within Ontario. They are selected to show how a street pattern re-aligned for passive solar gain can be accommodated in three differently shaped land assemblies. An optional plan, presented for each subdivision, is designed to allow the conservation of energy by using site layout. In all cases the alternative plans meet the requirements imposed on the original plan by the physical characteristics of the site, by the local by-laws, and the original housing mix.

Case 1

Base Plan

The topography of this approximately 28 ha (70-acres) development is relatively flat with a natural elevation change of approximately 10 feet over the entire site. The topography poses no particular drainage problems.

The access points are predetermined by adjacent development and the Master Plan for the area. The north-east collector road is single-loaded to provide an additional buffer from an adjacent institutional use.

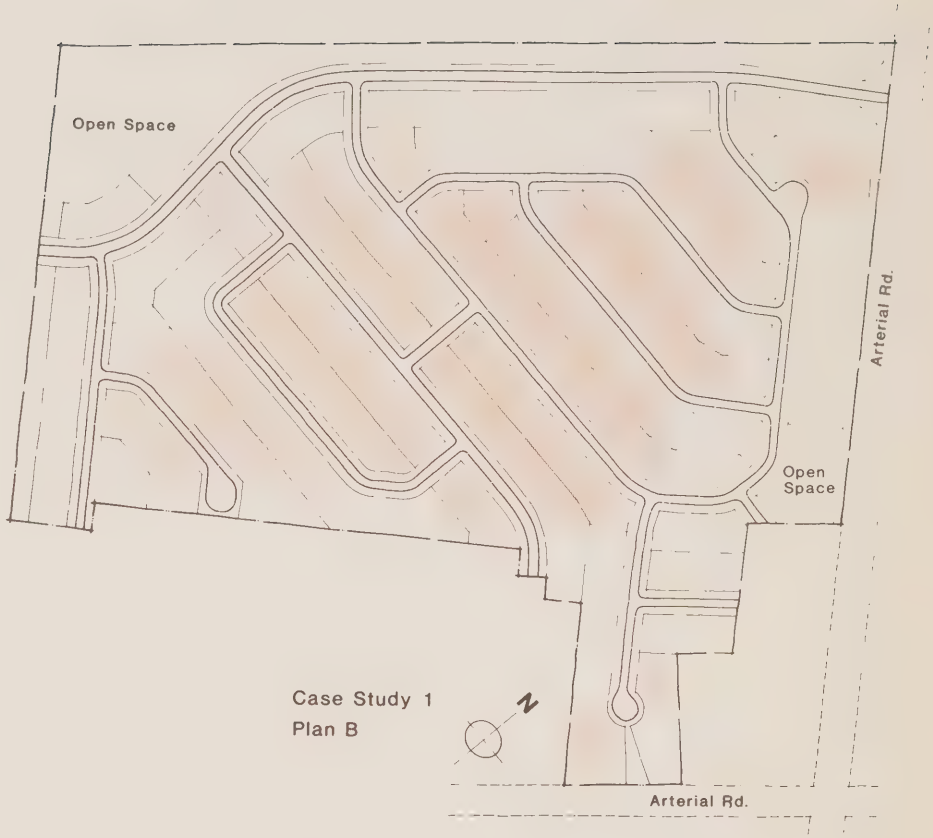
The street pattern is conventional with its alignment dictated by the boundaries of the land. The lots — for singles, semis and town houses — are typically 100 feet deep with only about 6 percent of the frontage satisfactory for north-south lotting.

Areas with south exposure.

Improved Plan

Maintaining the access points, lot size, street widths, drainage pattern, open space location and area, as in the base plan, the street pattern is changed to provide a greater number of streets with an east-west orientation. The consequences of the changes are:

- The length of roads remains virtually the same.
- The amount of frontage which allows north-south lotting is increased from about 6 percent to 55 percent.
- The saleable frontage is increased by about 900 feet/293 metres (or 22, 40′ lots).
- The traffic movement is improved.
- The areas requiring unconventional lotting to obtain proper exposure are reduced.



Areas with south exposure.

Case Study 1	Road Length	Saleable Frontage	Frontage with S. Orientation
Plan A	3490 m	4820 m	290 m
Plan B	3513 m	5113 m	2621 m

The conclusion is:

- A rigid east-west road alignment is not necessary to achieve a high degree of effective solar exposure.
- More careful planning results in increased revenues.
- The improved plan contains no more straight line roads than the base plan.

Case 2

Base Plan

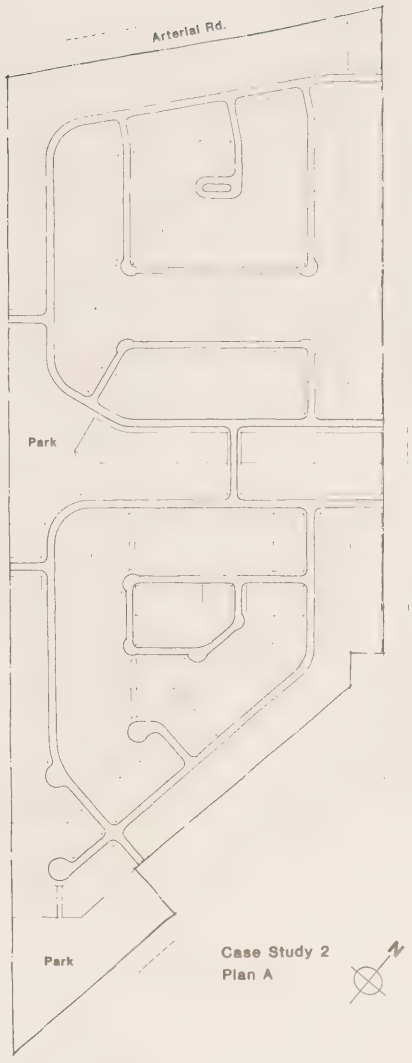
This 31.8 ha (78.7 acres) site contains a moderate easterly slope and its elongated shape, when handled in a traditional fashion, does not pose any major problems in terms of developing a street pattern. The traffic is channelled into two looped minor collectors on which, by not using semis and town houses, the number of access points is minimized. Because of the site orientation very few lots provide for a southerly orientation.

Improved Plan

As in Case 1, a north-south orientation of the lots is attained through greater use of east-west streets.

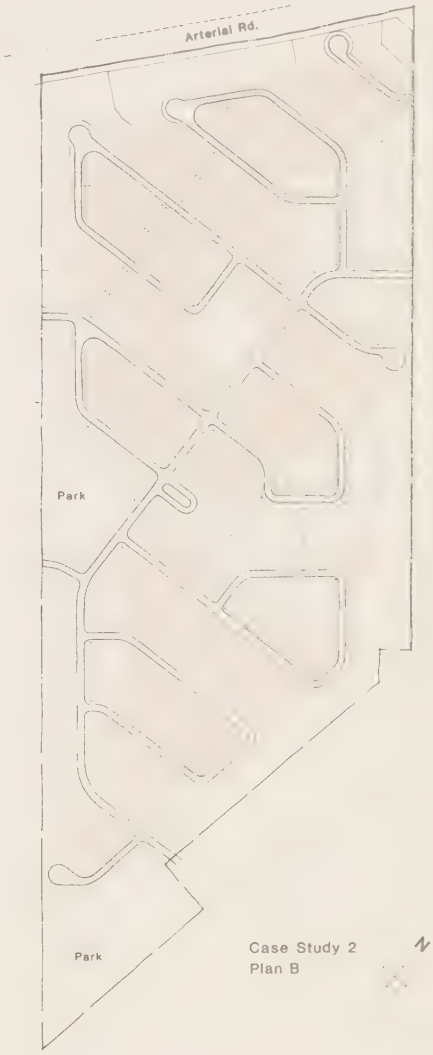
The results from the changes are similar to Case 1 but a little more pronounced.

- The saleable frontage is increased by well over 1000 feet. This could represent 35 to 40 additional lots.
- The street length remains almost the same, but the total acreage dedicated to roads decreases by 1.3 acres. This is the result of using only one collector road.
- There are less lengths of straight road in this plan.
- The north-south portion of the collector contains hardly any frontages.
- Over 70 percent of the lots are on a north-south orientation along their depth.
- Traffic movement is improved by creating a clearer hierarchy of roads.
- Better use is made of the natural drainage — practically eliminating sewers from a large portion of the collector road.



Areas with south exposure.

Case Study 2	Road Length	Saleable Frontage	Frontage with S. Orientation
Plan A	3863 m	6111 m	198 m
Plan B	3901 m	6523 m	3871 m



Areas with south exposure.

Case 3

Base Plan

This plan is the first development stage of a large assembly and covers approximately 50 ha (124 acres) of easterly sloping land.

The development is a low-density one (singles and semis) with a street pattern which produces lots with a generally east-west orientation.

Improved Plan

In developments with such low densities optimum building orientation is a must.

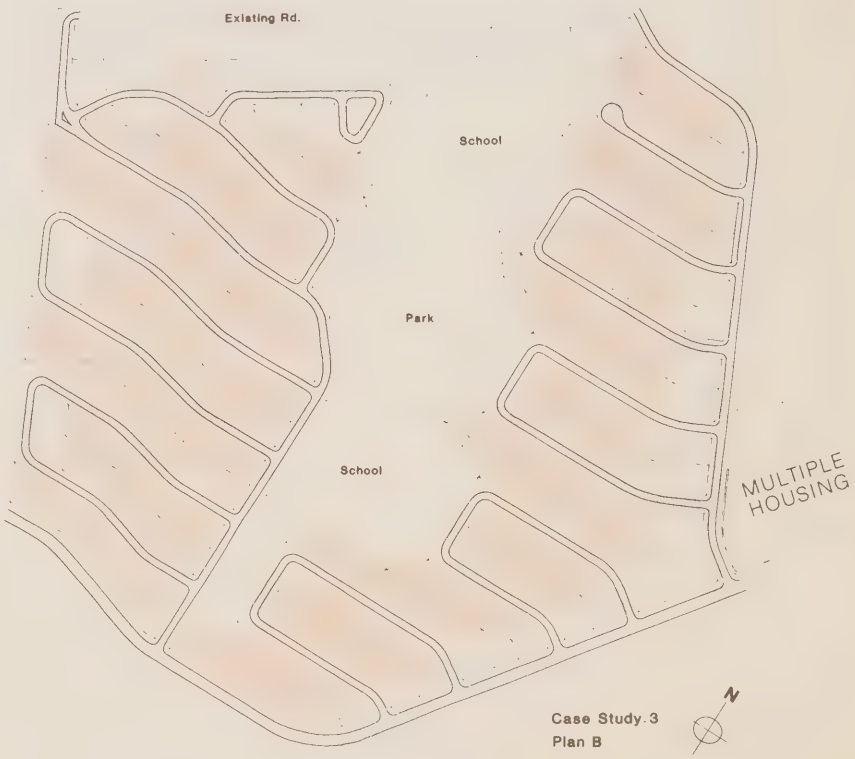
In this plan an east-west road pattern is provided so that a maximum number of lots can have a north-south orientation. As well, frontages on north-south streets are eliminated wherever possible.

The most salient features of the plan are:

- The saleable frontage is increased by 6774 feet/2198 metres (or 160, 40′ lots).
- The number of lots with a north-south orientation is increased from 10 percent to 70 percent.
- The parks/schools — relationship is improved. They are also more accessible to pedestrians.
- The large loops to the west are purposely curved to decrease long sight lines.

Case Study 3	Road Length	Saleable Frontage	Frontage with S. Orientation
Plan A	5608 m	7437 m	777 m
Plan B	5799 m	9635 m	6759 m

Areas with south exposure.



Areas with south exposure.

Conclusions

The main design issues identified in this document are:

- Streets are not required to be rigidly oriented east-west.

  The street pattern in an energy-efficient residential subdivision designed to use solar radiation is likely to produce more rectangular blocks than those found in the traditional curved street layout. This generally results in an increase in the number of lots and saleable frontage because of the more regular lotting arrangement.

- Although lots on the south side of an east-west street are normally narrower, there is no need to have more than a difference of 5 feet in width from those on the north side.

  This is achieved by the degree of incorporation of the garage into the width of the house.

Building arrangement in a cul-de-sac — All houses have the main facade facing south and no overshadowing occurs. The location of the trees is only schematic and serves to illustrate the general areas where evergreen and decidious planting should take place to be the most advantageous.

- There is a need to avoid detached housing fronting on north-south streets — unless special lotting or a flankage arrangement is used.

  Neither of these alternative arrangements results in a loss of yield.

- Special lotting at the end of cul-de-sacs is possible to maximize solar exposure.

  This arrangement generally leads to an extra lot being produced on a reduced block area.

- Skewed side lot lines on streets that are diagonal to an east-west orientation provide a satisfactory arrangement for solar exposure.

  Only a small skew is generally necessary.

- The relationship between lot orientation and window arrangement of a house is necessary to exploit solar radiation.

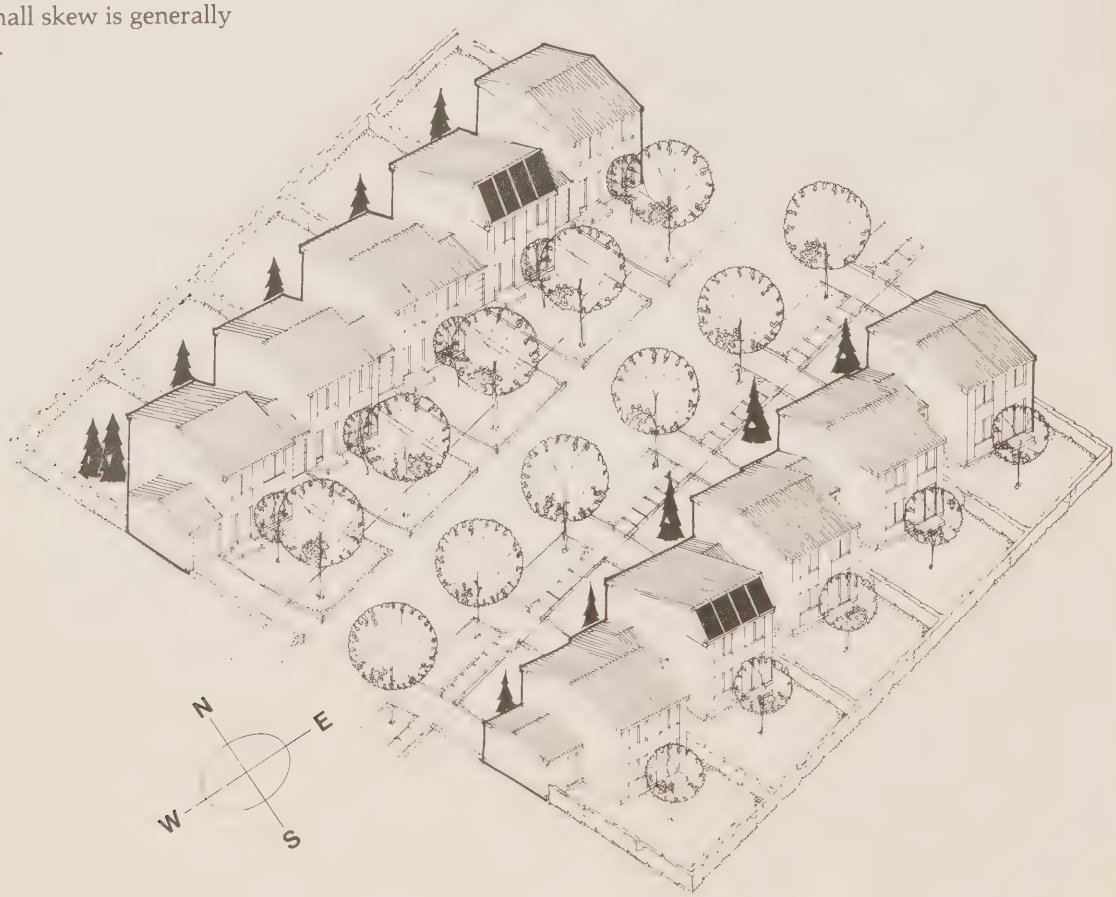
  In a subdivision which has the majority of lots providing a south orientation, this matching of house design and lots does not pose an additional problem to conventional subdivision development practice.

- There is a need to limit semi-detached and town housing on the north side of an east-west street because of the smaller area of window glass normally available for a south building face.

  The opportunity exists for location on the south side of east-west streets, because of the availability of window area on the building wall opposite to the garage entrance. Also, because of the superior energy efficiency resulting from shared walls, these units are satisfactorily located on north-south streets.

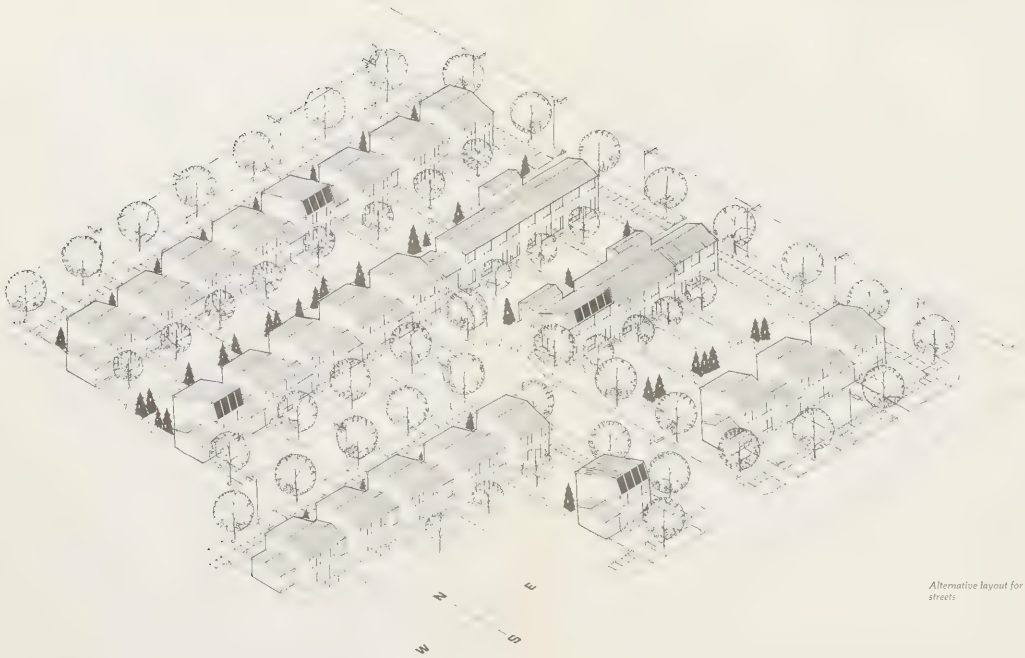
- Walls on the south side of an east-west street are limited in fenestration.

  This arrangement provides added privacy and the location of the larger windows on a south building face.



Buildings on a skewed street. In addition to adding variety to the street scene this arrangement creates private outdoor living areas.

Town-houses are ideally suited for north-south streets. Because they have the attached walls this building type is not sensitive to orientation.



Alternative layout for north-south streets

- The colours on the building faces are dark in order to better absorb solar radiation.

- Some roof designs include slopes that will allow the future addition of active solar equipment. This is not necessary to achieve energy savings in the type of passive solar subdivision planning discussed in this handbook, but it is an investment in the future when active solar waterheating units could come into wider use.

- Landscaping is not likely to show much change in cost or appearance from that usually employed.

  Blocks rather than lots are likely to be the basis on which landscaping will be designed. Evergreens are likely to be related to any lot landscaping.

Any aspect of disadvantage that may be related to the design changes associated with an energy efficient residential subdivision is possibly mainly visual, and the perception of this disadvantage is essentially qualitative. Conversely, not only are there the many advantages (for example, increased lot yield) over and above the saving of energy on space heating that have been discussed in this handbook, but, also, there is the improvement in the general living environment that comes from a better exposure to sunlight.

There are obviously a number of options that the municipality, developer, and consumer can consider. The objective of saving money by decreasing energy use is not likely to disappear in the foreseeable future. Ultimately, the consumer will decide how far and at what pace passive solar residential subdivision design should proceed. The Handbook hopefully will help both the understanding of the available options and the trade-offs involved. There is a reasonable assumption that the changes, when understood and adequately presented to the public, are beneficial enough to be relatively easily accepted.

Acknowledgements

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ISBN 0-7743-9548-6